

Multi-Channel Transcutaneous Cortical Stimulation System

Contract # N01-NS-7-2365

Progress Report #6

for the contract period 7/1/98 – 10/31/98

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Introduction

The goal of this project is the design, fabrication, and testing of a *Multi-Channel Transcutaneous Cortical Stimulation System* to be used in a prototype artificial vision system. During the past 25 years, the development of a neuroprosthesis which could be used to restore visual sensory functions has been an important goal of the Neural Prosthesis Program (NPP) of the National Institute of Disorders and Stroke, National Institutes of Health. Demonstrations of the feasibility of a visual prosthesis have reached the stage in which the NPP is highly motivated to initiate the development of a fully implantable cortical stimulation system which could be used to provide inputs and computer control for hundreds, to over one thousand, implanted cortical electrodes. This project uses the combined capability four organizations, the Illinois Institute of Technology, BioElectric Inc., Cross Technology, and the A.E. Mann Foundation to accomplish this challenging task.

This is the sixth progress report for this project. In this report we describe our progress on the glass-sealing of the ceramic package for the 64-channel submodules and our progress on the ASIC designs.

Progress on Design of the Implant Package

In our fifth progress report we reported that we were investigating the use of a low-temperature glass which had been formulated to match the temperature coefficient of the Macor ceramic. During the last quarter, we also reported that we had obtained sheets of the Macor and planned to use it as the ceramic material for the submodule package. This decision was based upon our tests in which we were able to machine very intricate patterns using a sophisticated NC milling machine. All of the features required by our design are easily machined directly from our CAD drawings. Using the Macor has eliminated major concerns associated with the laser machining of the aluminum oxide. We obtained two different samples of candidate glasses, for the seals, and proceeded to use our glass microscope slide method to investigate the quality of the seals. We outfitted our lab with suitable furnaces and processing equipment, and fabricated prototype glass packages. Once establishing the feasibility of using the Macor, and the glass seals, by testing in the bubble-vacuum test, we worked to determine methods of precise deposition of the glass in the patterns required for the ceramic submodules.

Two types of glass were evaluated: a vitreous type (#41), and a crystalline type (#42). Both of the glasses have firing temperatures in the range of 370° - 380° C. This range is low enough to prevent deterioration of the thin-film metal which is to be used for interconnects and feedthroughs in the submodules. We prefer the #42 type glass because the crystalline type can be reheated without the glass returning to a liquid state. Since the sealing process involves 3 different seals, made in succession, we consider this an advantage.

We initially tried to deposit the glass, in the green-state, by using water as a vehicle. The results from these tests were variable and the deposition was difficult to control. We then used a commercially available oil-based vehicle. This method proved much easier to control. Using an air-driven syringe, in combination with a modified X-Y plotter, we were able to form seals of less than 0.04" wide, and less than 0.001" thick. A photograph of a Macor sheet, machined to

the shape of the submodule package, and sealed to a sheet of clear glass is shown in Figure 1, below.

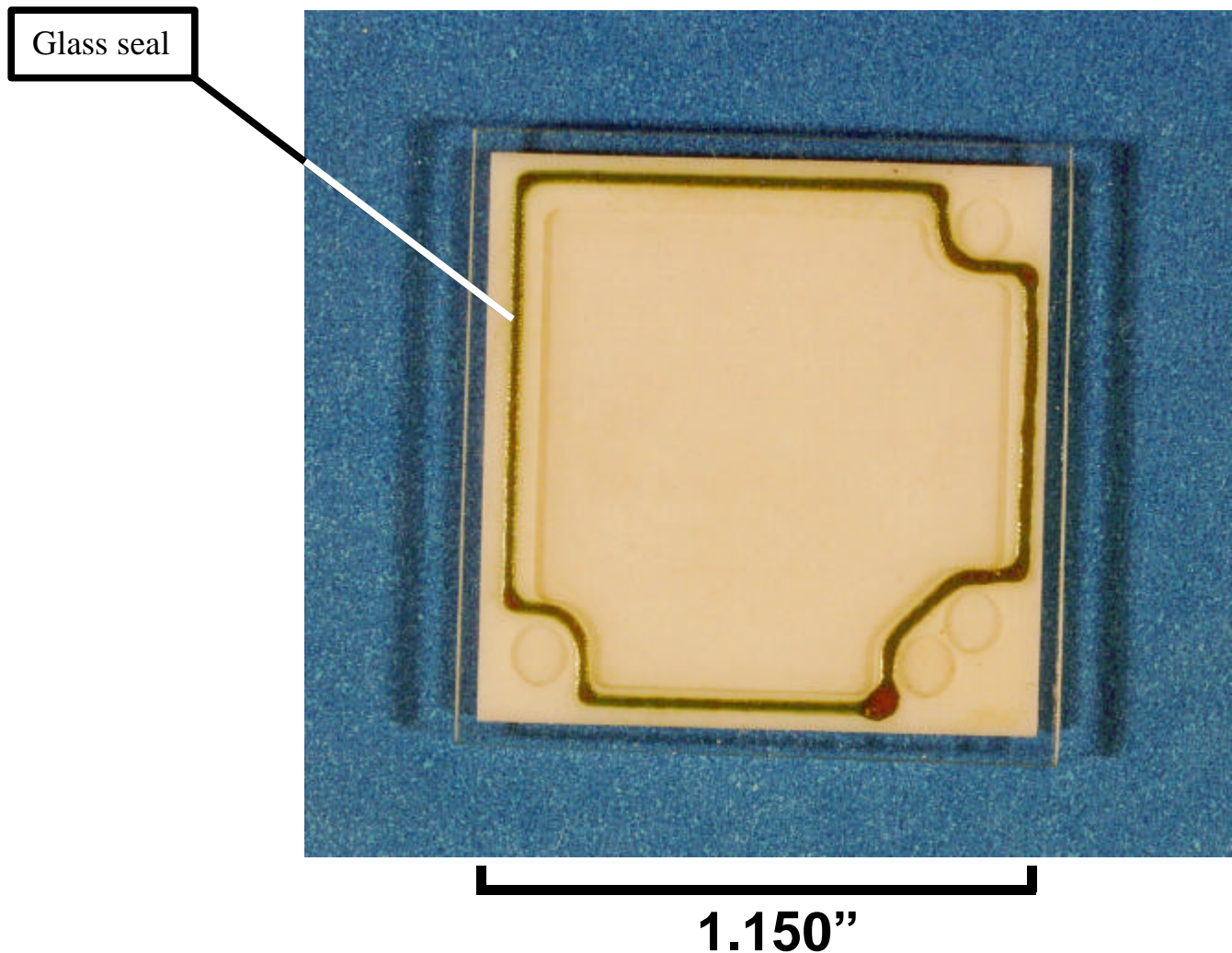


Figure 1- Macor sheet, machined to the shape of the submodule, and sealed to a sheet of glass.

We have also tested the #42 glass for corrosion during high-temperature saline soak. Samples of the glass-to-glass sealed microscope slides were soaked in 90° C saline for over 60 days. During that time we saw no deterioration of the glass material, even under 500X microscopic examination. We are continuing these tests. During the next quarter we plan to send ceramic-to-ceramic sealed packages to the Mann Foundation for more extensive leak testing.

During this quarter we also tested our ability to deposit the 0.001” thick gold on the edge of the Macor, in anticipation of the formation of the connector contacts. Samples of the Macor were sent to Cross Technology who used sputtering to deposit the thick gold. These samples were then sent to BioElectric for cutting of the connector contact pattern. This effort was highly successful. A photograph of one of these samples can be seen in Figure 2, below.

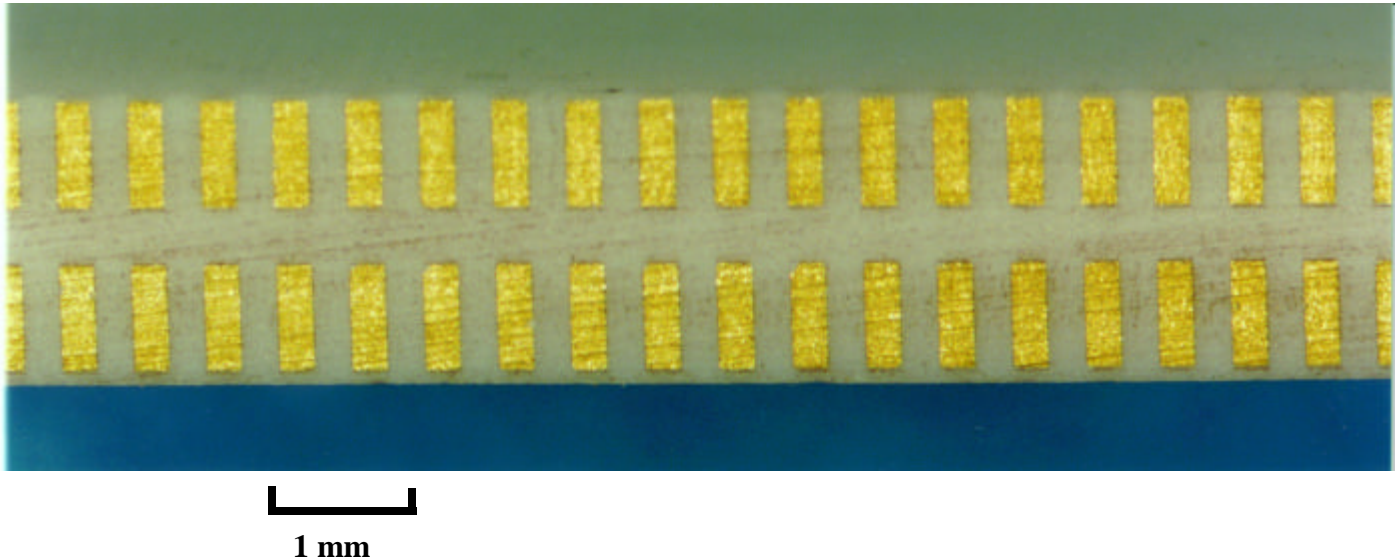


Figure 2 – Microphotograph of ceramic edge with pattern of gold connector contacts.

We also received samples from Electrofilms on which the coil pattern and 90-degree test pattern had been deposited. The 90-degree test pattern will be used in prototype packages to test the connectors and package hermeticity *in-vivo*. These samples showed excellent pattern detail. Electrical measurement of the printed inductor showed that its inductance was 5.5uH, with a Q of 2. These samples did not have the additional gold plating to lower the resistance of the coil traces. We expect to receive new samples next quarter and anticipate a coil Q of approximately 13. A photograph of an Electrofilm sample can be seen in Figure 3, below.

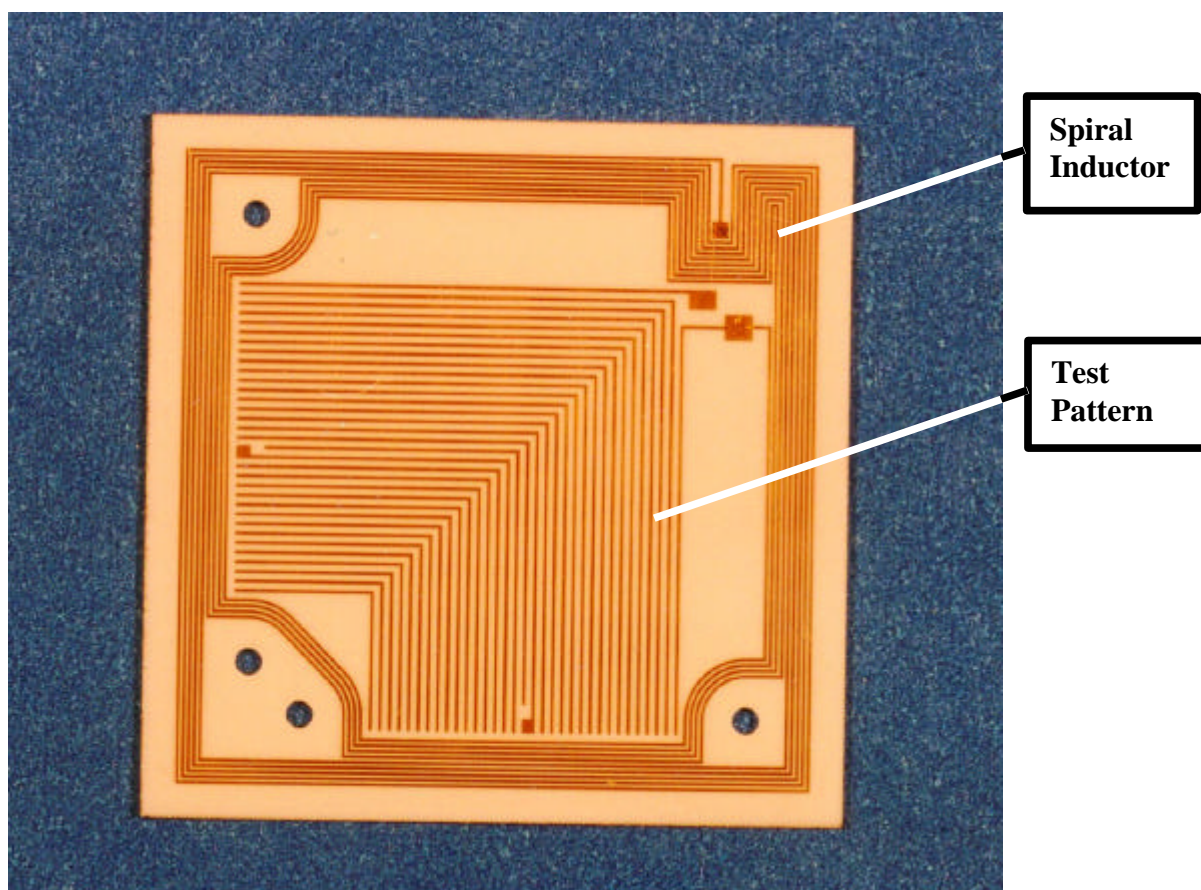


Figure 3 – Prototype of Layer#1 ceramic

During the next quarter we plan to evaluate the use of a screen printer and an X-Y table for better control of the glass seal deposition, and we intend to fabricate packages using the 0.015" thick ceramic material.

Progress on the design and fabrication of the submodule ASICs.

During the past quarter we have tested ASICs BLOCK1 and BLOCK2. The designs, simulations, and layouts, were performed at IIT. Fabrication was accomplished by AMI through the MOSIS fabrication service. We have also fabricated MOS10, for testing our sample-hold cells. The sample-hold circuitry will be used for the measurement of the electrode voltages.

Testing of BLOCK1 and BLOCK2

During an earlier quarter, we had identified an anodic/cathodic balance problem in DAC6 which we believed was associated with impact ionization of the output driver transistors. We had revised our DAC design using extremely conservative guarding of the DAC reference

mirrors to eliminate this effect. This new design was contained in MOS9, which we described in our last report.

BLOCK1 and BLOCK2 contained complete address decoders, data latches, and timers that were needed for the final 8-channel Block chip designs. BLOCK1 used all poly2 transistors. BLOCK2 used extended drain transistors to correct for operating point differences between the current mirrors in the reference and those in the individual DAC cells.

In evaluating BLOCK2, we found an improvement in the anodic-to-cathodic matching. For some DACs the match was as close as 2%. However, for other DACs the mismatch was larger, up to 15%. In order to achieve a wide compliance voltage range, we used a unique regulation of the current mirror voltages. Variations in the offset voltage of the voltage regulators is responsible for the DAC-to-DAC variations. We are correcting this offset problem and plan to fabricate a new ASIC during the next quarter.

The use of the voltage regulators to expand the DAC compliance voltages was highly successful. Below, we show a slide presented at the Neuroprosthesis Workshop, in October of 1998, which shows the technique and the resulting DAC performance.

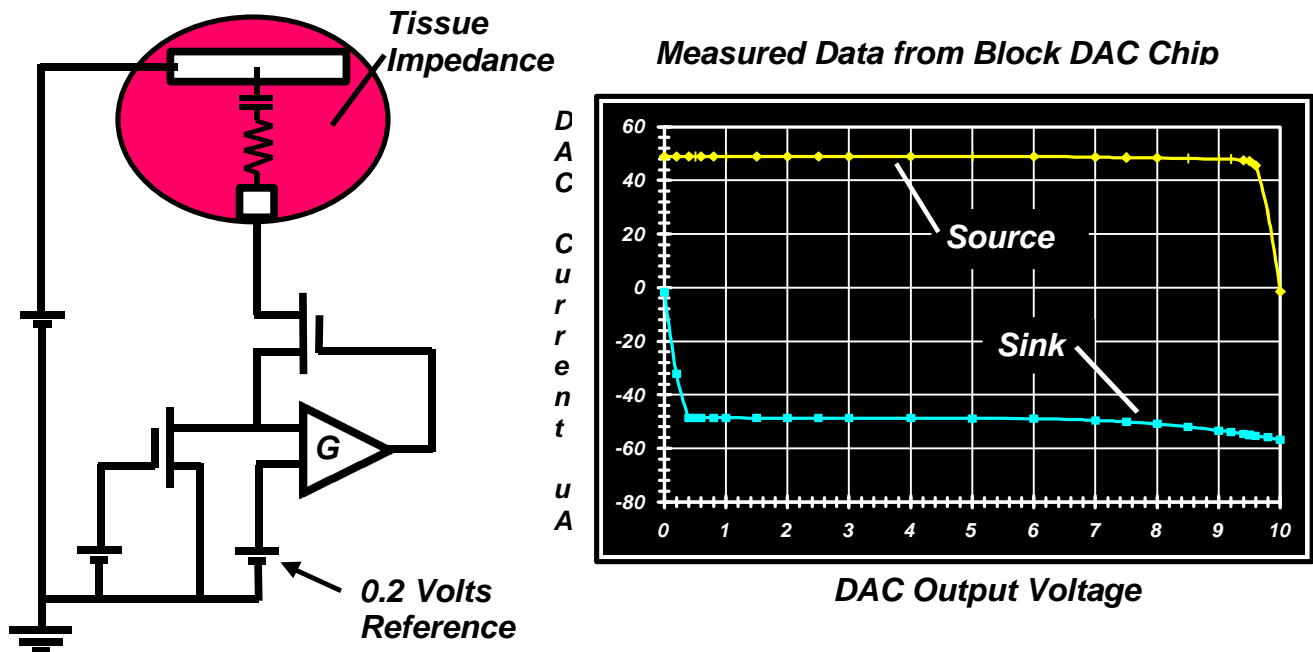


Figure 4 – Plot of DAC output current vs. DAC output voltage

Note in Figure 4, that the DAC current is constant for almost the entire range of voltage. For this test the indifferent electrode is connected to +5VDC. The minor increase in DAC sink current, near 10 volts, is a consequence of lithographic transistor variations and will be compensated for in our revised design using larger transistors.

We feel that the performance of this DAC is adequate to use in laboratory testing at NIH, and we have included the BLOCK2 design in a recent AMI wafer run made by the Mann

Foundation. We expect a large supply of these chips to be available by the end of 1998. We are presently planning to fabricate a computer controller for the BLOCK2 chip which will permit its use, at NIH, for driving microelectrodes.

Design of the Sample-Hold circuitry.

During this quarter we designed, and submitted for fabrication, our first cells to be used for the block chip electrode voltage monitors. Called MOS10, this ASIC contains a revised (smaller) bridge design, a DAC with test points, a sample-hold cell, and a prototype A/D converter. We anticipate receiving MOS10 during the next quarter and testing its operation.